(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 247 628 B1**

(12) EUROPEAN PATENT SPECIFICATION

(45) Date of publication of patent specification: **03.08.94** (51) Int. Cl.[5]: **B23K 9/10**

(21) Application number: **87107832.5**

(22) Date of filing: **29.05.87**

(54) Method of control and apparatus for hot-wire welding.

(30) Priority: **30.05.86 JP 124869/86**
04.07.86 JP 156253/86

(43) Date of publication of application:
02.12.87 Bulletin 87/49

(45) Publication of the grant of the patent:
03.08.94 Bulletin 94/31

(84) Designated Contracting States:
DE GB SE

(56) References cited:
EP-A- 0 139 249
US-A- 4 467 176

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Description

The present invention relates to a method and an apparatus for controlling a hot-wire welding process in which magnetic arc blow and splattering are eliminated and the heating power of the hot-wire can be maintained automatically at a proper value.

Fig. 1 shows the configuration of a welding apparatus used conventionally for the hot-wire TIC welding process.

A tungsten electrode 2 making up an arc electrode in the TIG welding torch 1 and a base metal 3 are connected to a welding arc power supply 4 directly, and an arc 5 is formed with the tungsten electrode 2 as a negative electrode in an argon shielding gas. A welding filler wire 6 is supplied from a wire feeder 7 through a conduit 8 and a contact tip 9 connected therewith to the arc forming section and is contacted with the base metal 3. The contact tip 9 and the base metal 3 are connected to a wire heating power supply 10. A direct or alternating current is supplied to the filler wire 6 thereby to generate Joule heat, thus improving the melting rate of the filler wire 6.

The optimum molten state of the filler wire 6 in the hot-wire TIG welding process is such that the filler wire 6 is completely molten immediately before entering the molten pool 11 and the molten metal continues to drop without interruption. In such a case, the metal is melted, and the molten metal flows to the molten pool 11 as if hot water is poured from a kettle, thus forming a superior bead 12.

For this purpose, it is necessary to control the filler wire 6 to be energized and heated in the portion extension $\underline{e}$ between the contact tip 9 and the base metal 3 in such a manner that a balance is achieved between the power supplied thereto and the wire melting amount.

In the hot-wire TIG welding process, however, it is conventionally known that with the increase in the wire energization current, an electromagnetic force is generated with the arc current, which causes what is called "magnetic arc blow", making the welding difficult.

As a measure against this inconvenience traditionally known and employed from old days as a common technical knowledge, an arc current as high as possible is selected to increase the stiffness of the TIG arc, and the wire heating current is set to less than one half of the arc current, and the wire is heated with AC rather than DC current. In order to increase the wire-melting rate, however, it is necessary to increase the wire current. As a result, if a proper arc current is selected for a given object of welding to obtain a wire melting rate of, say, 20 g/min, a magnetic arc blow may occur continuously unless the arc is set to a very short length of less than 1.5 mm, thus making the welding work difficult. This conventional method, therefore, has been limited in its applications.

In the prior art, the power for heating the wire is controlled in such a manner that while the extension $\underline{e}$ is kept as constant as possible during the welding work, the wire melting conditions are observed by the welding operator to adjust the wire power in accordance with the wire feed rate, based only upon the intuition and experience of the welding operator.

In contrast, US 4 614 856 proposes a method of controlling the applied power to a value matching the wire feed rate by measuring the power applied to the extension $\underline{e}$ during the welding work.

Specifically, in view of the fact that the amount of heat necessary for melting the wire is proportional to the applied power in principle, the applied power is supplied in proportion to the wire feed rate.

As a result, by the welding operator adjusting the proportionality constant, a great variation in the extension $\underline{e}$ or a considerable change of the wire feed rate in the welding are possible.

Even though proper conditions are determined in this way, to keep subsequent conditions, the arc current, the arc length or the angle of inserting the filler wire 6 into the molten pool 11 may cause a change in the amount of heat transferred to the filler wire 6 from the arc 5 or the molten pool 11, so that the melting conditions somewhat change, thereby causing a deviation from the proper melting state.

If the applied power deviates towards an excessive wire feed rate, "splattering" occurs generating spatters, and the arc 5 is disturbed by the current passing through the arc between the tip of the filler wire 6 and the base metal 3 or the tungsten electrode 2. These phenomena disturbe the welding operation very much. In the event that the applied power becomes too small for the wire feed rate, on the other hand, the apparent arc conditions remain substantially unchanged, and the welding operator continues to proceed with his work without noticing the change of the conditions, with the result that unmolten wire 13 is left in the deposited metal 14 often forming a welding defect as shown in Fig. 2. To prevent these troubles, the welding operator has to observe the molten part of the wire or the arc as frequently as possible during this welding work, checking to see whether the proper welding conditions have been kept while adjusting the applied power. This decision as to whether proper conditions are maintained depends on the intuition of the welding operator.

Accordingly, it is the main object of the present invention to provide specific means for solving the above-mentioned problems, or in particular, to provide specific means for maintaining the melting conditions of the filler wire at an optimum state fully automatically in the hot-wire TIG welding process without relying on the intuition or requiring any operation by the welding operator.

A further object of the present invention is to provide a hot-wire welding apparatus in which spatters are prevented from being formed or reduced greatly, thereby making allowing to continue hot-wire welding over a long time.

The above object is achieved according to the independent claims. The dependent claims relate to preferred embodiments.

The method of the present invention for the welding control in a hot-wire welding apparatus comprising an arc power supply, an arc electrode connected to the arc power supply, a filler wire leading to a molten pool, and a wire-heating power supply for heating by energization of the filler wire, is characterized in that a pulse-like direct or alternating current is applied to the filler wire, and, during the de-energizing period of the pulse current, it is detected whether or not the filler wire is in contact with the molten pool, and the current applied to the filler wire is inhibited during the subsequent energizing period when it has been detected that the filler wire is not in contact with the molten pool.

According to another aspect of the present method, the heating power is increased until the filler wire is fused, and the wire heating power after fusing the filler wire under excessive heat is set lower than the heating power immediately before the fusing of the filler wire, and the wire-heating power is again gradually increased from the lower setting until the filler wire is again fused under excessive heat.

The hot-wire welding apparatus of the present invention comprises an arc power supply, an arc electrode connected to the arc power supply, a filler wire leading to a molten pool, a wire-heating power supply for heating by energization of the filler wire, a control circuit for controlling the heating power applied to the filler wire, which produces a pulse-like direct or alternating current, and a wire contact detector circuit which electrically detects during the de-energizing periods of the pulse current whether or not the filler wire is in contact with the molten pool, and wherein the control circuit inhibits the current applied to the filler wire during the subsequent energizing period when it has been detected that the filler wire is not in contact with the molten pool.

In accordance with another aspect of the present welding apparatus, the control circuit controls the heating power applied to the filler wire such that the heating power is increased until the filler wire is fused, and the wire heating power after fusing the filler wire under excessive heat is set lower than the heating power immediately before the fusing of the filler wire, and the wire-heating power is again gradually increased from the lower setting until the filler wire is again fused under excessive heat.

According to a preferred embodiment, the above defined hot-wire welding apparatus further comprises

a wire contact detector circuit including

a terminal voltage detecting circuit for detecting, during a de-energizing period of the pulse current, the terminal voltage of the filler wire or the output terminal voltage of the wire heating-power supply, and

a comparator circuit for comparing the detected voltage from the terminal voltage detecting circuit with a predetermined reference voltage to detect whether or not the filler wire is in contact with the molten pool during the de-energizing period of the pulse current, so that when the filler wire is not in contact with the molten pool during the de-energizing period of the pulse current, a signal is put out to inhibit the energization during the energizing period of the pulse current immediately following the de-energizing period of the pulse current.

In accordance with another preferred embodiment, the hot-wire welding apparatus further comprises

a wire contact detector circuit for electrically detecting the contact condition of the filler wire with the molten pool, and

a circuit for controlling the heating power supplied to the filler wire so that when the wire contact detector circuit generates a signal indicating a transition from the contact condition to a wire separated condition, the heating power supplied to the filler wire is decreased, and when the wire contact detection circuit generates a signal indicating that the filler wire is in contact with the molten pool, the heating power supplied to the filler wire is gradually increased.

The welding apparatus may further comprise a fusing detector circuit for detecting a process of fusing of the filler wire by heat during an energizing period of the filler wire, and the control circuit instantly and rapidly reduces the wire current or stops the energization for the pulse period of the pulse current on the basis of a fusing detection signal from said fusing detector circuit.

The fusing detector circuit may be adapted to detect the fusing process of the filler wire from a change in the differentiated waveform of the wire currents or from a change in the wire voltage waveform.

The welding apparatus may further comprise a circuit including a semiconductor switching element connected in parallel to the filler wire, and the energization current for the filler wire is sharply reduced by shunting the current with the semiconductor switching element turned on.

According to another embodiment, the welding apparatus further comprises a controller for reducing the energization current for the filler wire by shunting, and either for restarting the wire energization after a predetermined period following the detecting that the wire has come into contact with the base metal again during the deenergization period of pulse current, or for restarting the wire energization after feeding a predetermined amount of the filler wire following the detection that the filler wire has come into contact with the base metal during the pulsed current deenergization period of the pulsed current.

The power supply may produce a pulsed current on the basis of a control signal from a circuit for determining a wire de-energization period.

In accordance with another preferred embodiment, the welding apparatus further comprises a circuit for forming a reference time interval, and the control circuit increases the increase rate of the wire-heating power, when the time interval of signals from the fusing detector circuit and/or the wire contact detector circuit is longer than a reference time interval, and reduces the increase rate of the wire-heating power when said time interval is shorter than the reference time interval.

According to still another preferred embodiment, the welding apparatus may further comprise a reference signal circuit for forming a reference time interval, and the control circuit increases the wire-heating power by a predetermined amount when the time interval of signals from the fusing detector circuit and/or the wire contact detector circuit is longer than the reference time interval, and reduces the wire-heating power by a predetermined amount when said time interval is shorter than the reference time interval.

The welding apparatus of the invention may further comprise a power signal circuit for producing a signal corresponding to the wire-heating power and the square of the effective value of the wire current in proportion to the wire feed rate, and the control circuit then controls the power applied to the filler wire by regulating the proportionality constant thereof.

In accordance with still another preferred embodiment,

- the control circuit comprises a semiconductor switching element;
- a setting circuit is provided for setting a voltage ramping rate and a voltage reduction margin;
- the reference or power signal circuit receives a signal from the wire contact detector circuit and a voltage from the setting circuit, and puts out a voltage to the control circuit for controlling the energization period of the pulse current,

  and
- the control circuit comprises a pulse forming circuit receiving a signal from the wire contact detector circuit and the voltage from the reference or power signal circuit, for controlling the energizing period of the wire heating pulse current by operating the switching element in proportion to the voltage from the signal producing circuit when the wire contact detector circuit generates the contact signal, and for inhibiting energization of the filler wire for a predetermined period and restarting the wire energization thereafter by operating the switching element when the wire contact detector circuit generates the noncontact signal.

According to a further embodiment, the welding apparatus may comprise

a current differentiation sensor for detecting the wire current and for putting out a signal of the differentiated waveform of the wire current, and

a controller which receives the signal from the current differentiation sensor, for detecting the wire condition immediately before fusing and rapidly decreases the wire heating current of the control circuit.

Preferred embodiments of the present invention will now be described in conjunction with the accompanying drawings, in which:

Fig. 1 is a diagram showing the configuration of parts of a hot-wire TIG welding apparatus according to the prior art;

Fig. 2 is a diagram showing a sectional view of the welding bead in Fig. 1;

Fig. 3 is a diagram showing a first embodiment of a wire-heating power supply and a control circuit according to the present invention;

Figs. 4 and 5 are diagrams showing wire terminal voltage waveforms of the wire-heating power supply of Fig. 3;

Fig. 6 is a diagram for explaining the control operation of the embodiment of Fig. 3;

Fig. 7 shows the configuration of the wire contact detector circuit 21 shown in Fig. 3;

Fig. 8 is a diagram showing the configuration of the energization phase control voltage forming circuit 23 and the voltage ramping rate and voltage reduction margin setting circuit 24 of Fig. 3;

Fig. 9 is a diagram for explaining the operation of the circuits of Figs. 7 and 8;

Fig. 10 is a diagram showing the wire terminal voltage in the case where a power supply of inverter type is used for heating the wire according to a second embodiment of the present invention;

Fig. 11 is a circuit diagram showing a third embodiment of the wire-heating power supply and the control circuit according to the present invention;

Fig. 12 is a diagram for explaining the control operation of the third embodiment of Fig. 11;

Fig. 13 is a circuit diagram showing a fourth embodiment of the wire-heating power supply and the control circuit according to the present invention; and

Fig. 14 is a diagram showing waveforms of the wire-heating power supply and the output voltage in the case where a circuit of inverter type is used as the wire-heating power supply according to a fifth embodiment of the present invention.

Fig. 3 shows an embodiment of a wire-heating power supply and a control circuit according to the present invention. This first embodiment uses a triac system which can be configured at very low cost as a wire-heating power supply for producing a pulse current. This power supply circuit replaces the wire-heating power supply 10 of the hot-wire TIG welding apparatus of the prior art shown in Fig. 1.

In this embodiment, as shown in Fig. 3, the primary winding of a main transformer 15 is connected to a triac 16, and the secondary winding thereof to a full-wave rectifier circuit including diodes 17, 18, making up a wire-heating current-forming circuit 19. This wire-heating current-forming circuit 19 has the triac 16 controlled by a gate pulse-forming circuit 20 to produce a wire current with the AC power supply of commercial frequency subjected to phase control. In order to prevent continuous magnetic arc blow or to limit a magnetic arc blow to an instantaneous phenomenon for facilitating the welding work which otherwise would be hampered by the magnetic arc blow, the application of a gate pulse to the triac 16 is always controlled in such a way that the de-energization period lasts from zero to 90 degrees and from 180 to 270 degrees in the commercial frequency phase. The phase control angle for energizing the triac 16 is thus within the remaining period from 90 to 180 degrees and from 270 to 360 degrees to energize the filler wire 6 shown in Fig. 1 in a manner to produce a wire-heating power commensurate with the wire feed rate.

The wire terminal voltage (output terminal voltage) represented by Vw during the wire de-energization period assumes almost 0V as shown in the period x of Fig. 4 when the filler wire 6 is in contact with the base metal 3, and a negative voltage below. -1 V by detecting the voltage of a plasma flame when the wire tip is away from the base metal 3 and in contact with the arc plasma as shown in the period y of Fig. 5. Taking advantage of this characteristic, a wire contact detector circuit 21 for detecting whether the tip of the wire 6 is in contact with the base metal 3 is configured appropriately. The output voltage Va of the wire contact detector circuit 21 takes a "high" (H) level when the wire 6 is in contact with the base metal 3, and a "low" (L) level when it is away from the base metal. This signal is applied to an on-off control circuit 22 in the gate pulse-forming circuit 20 which is operated such that the next energization pulse is not formed if the wire 6 is detached from the base metal 3.

The energization phase control voltage-forming circuit 23, on the other hand, is supplied with a signal from the voltage ramping rate voltage reduction margin setting circuit 24, as well as the output voltage Va of the wire contact detector circuit 21, and produces a voltage Vb for determining the energization phase of the triac 16 applied to the energization phase control circuit 25 in the gate pulse forming circuit 20. This output voltage Vb gradually increases when the output voltage Va is high, that is, when the wire 6 is in contact with the base metal 3, while when the voltage Va is reduced to low level (L), that is, when the wire 6 comes away from the base metal 3, the voltage V_B is decreased by a predetermined value.

Fig. 6 shows changes in the voltage signal and the output current with time. The energization phase control circuit 25 in the gate pulse-forming circuit 20 controls the firing angle in such a manner as to increase the energization current in accordance with the magnitude of the input voltage Vb. With increasing energization current, the resistance of the extension $\underline{e}$ indicated in Fig. 1 and the wire-heating power determined by the energization current for the extension $\underline{e}$ naturally increase, and when the applied wire-heating power increases as compared with the wire feed rate, the wire 6 is overheated and molten like a fuse. The wire 6, once molten, comes away from the base metal 3, and the resultant change in the output voltage Vw is detected by the wire contact detector circuit 21, thereby reducing the output Va to low level. As a result, the wire energization is inhibited, and the energization phase control voltage-forming circuit 23 reduces the output voltage Vb by a predetermined value. When the tip of the wire 6 comes into contact with the base metal 3, and the voltage Va rises to high level to resume the wire energization, the power applied to the wire 6 is set to a value slightly lower than the optimum heating power required for the wire feed rate.

In this operation, if the wire feed rate is reduced during the welding work, the wire 6 tends to be overheated, and therefore the wire is fused so frequently that the voltage Vb gradually drops, resulting in the wire-heating power being reduced. If the wire feed rate increases, by contrast therewith, the wire-heating power tends to be insufficient, and therefore, although the wire is not fused, the energization phase control voltage-forming circuit 23 operates to increase the voltage Vb gradually, with the result that the wire-heating power continues to increase until the wire is fused.

According to the present invention, the functions remain the same even when the wire extension e changes. Specifically, with an increase in the extension e, the resistance value thereof increases. When the wire-heating power supply has a constant-voltage output characteristic, therefore, the crest value of the current decreases given a constant energization phase, so that the output power decreases, thus making fusing difficult. As a result, the output voltage Vb gradually increases to increase the energization phase, thereby leading to a heating power commensurate with the wire feed rate. When the extension e shortens, by contrast therewith, the resistance value in the extension e is decreased, and for the same energization phase the current crest value increases, causing an excessive applied power to facilitate fusing. Each time of detachment the voltage Vb drops, and the energization phase decreases, with the result that the initial heating power commensurate with the wire feed rate is achieved.

The degree of the Vb drop each time of wire detachment, or the rate at which the output voltage Vb increases subsequently is determined by controlling the variable resistor provided in the voltage ramping rate/reduction degree setting circuit 24 for selection and control at a proper value before or during the welding process.

In this manner, the control operation is performed following the changes in wire feed rate and extension e during the welding operation, and therefore, it is possible to keep a value very near to the proper wire heating power automatically.

Fig. 7 is a diagram showing the configuration of the wire contact detector circuit 21 of Fig. 3.

In Fig. 7, the AC source voltage Vin of commercial frequency is applied to a zero-cross signal forming circuit 211 thereby to form a pulse signal for phase zero. On the basis of this signal, a wire deenergization period setting circuit 212 produces a "high" signal for the period of $\pi/2$, during which a sample-hold circuit 213 keeps the wire voltage Vw conducting and applies it to a comparator circuit 214. Then, when the wire energization period is started and the output of the wire de-energization period setting circuit 212 becomes "low", the immediately-preceding value of Vw is held and applied to the comparator circuit 214. The comparator circuit 214 compares the signal from the sample-hold circuit 213 with the voltage from the reference voltage setting circuit 215, and decides whether the wire 6 is in contact with the base metal 3, and forms an output signal Va.

Fig. 8 is a circuit diagram showing the configuration of the energization phase control voltage-forming circuit 23 and the voltage ramping rate/voltage reduction range setting circuit 24 shown in Fig. 3.

In Fig. 8, the output Va of the wire contact detector circuit 21 is applied to a timer T in the energization phase control voltage forming circuit 23. The timer T produces a signal Q which becomes "high" when the output Va changes from "high" to "low" level, and a signal $\overline{Q}$ subject to the opposite change. When the signal $\overline{Q}$ is "high", a first analog switch AS1 in the energization phase control forming circuit 23 turns on, so that a low-voltage source E, a first voltage ramping rate control VR1 and a capacitor C are connected in series thereby to promote the charging of ,the capacitor C. When it is detected that the wire 6 in Fig.1 comes away from the base metal 3 to such an extent that the output Va becomes "low", the signal Q becomes "high" during the period t_0, and the second analog switch AS2 turns on, so that the capacitor C is grounded through a second voltage reduction range setting resistor VR2 and thus proceeds to discharge, with the result that the voltage across the capacitor C drops. The voltage of the capacitor C is produced as an energization phase control voltage Vb through an amplifier Amp 1 inserted in the energization phase control voltage forming circuit 23.

Fig. 9 shows the manner in which the output voltages Va, Vb and the states of the analog switches AS1, AS2 change with time.

In the apparatus shown in Fig. 3, the cycle of fusing by overheating of the wire 6 depends mainly on the change in the power applied to the wire 6 and the feed rate of the wire 6. Although the fusing of the wire 6 by overheating may be accompanied by very small spattering, it is desirable to reduce the frequency thereof. For this purpose, in the event that it is necessary to meet rapid changes in the extension e or the feed rate of the wire 6, the rate of increase and the degree of reduction in the voltage Vb is increased, thereby to cause frequent fusing of the wire 6. In the case where a change in the extension e or the feed rate of the wire 6 is not frequent, on the other hand, the increase rate and the degree of drop of the voltage Vb are reduced, thereby to reduce the frequency of fusing by overheating of the wire 6. The change in the power applied to the wire 6 is determined normally by manual control of the variable resistor of the voltage ramping rate/reduction range setting circuit 24 before or during the welding process. This control may also be performed automatically by means of a circuit for controlling the wire-heating power in such a manner that the intervals of fusing by overheating of the wire 6 approach a designated value, in which a time interval of fusing by overheating of the wire 6 is predetermined, so that when the actual fusing interval is longer than the predetermined value, the wire-heating power is increased at a higher rate, while if the actual fusing interval is short, the wire-heating power is increased at a lower rate.

In similar fashion, automatic control of the applied power for heating the wire 6 is alternatively possible by a circuit for controlling the wire-heating power in such a way that the interval of wire fusing under excessive heat is adapted to approach a predetermined value, in which an interval of wire fusing by overheating is predetermined, and when the actual interval of fusing is longer than the predetermined value, the power for heating the wire 6 is increased by a predetermined amount, while, when the actual interval is shorter, the wire-heating power is reduced by a predetermined amount.

If a high wire current flows in the moment of fusing of the overheated wire, spatters are liable to form. If the wire current is comparatively low, below 100 A, or no current flows, on the other hand, no spatter is formed. In the case where a wire-heating power supply is used for producing a pulsed current, it is possible to reduce the spatters formed remarkably by use of a circuit for controlling the fusing by overheating of the wire or the detachment of the wire from the base metal to occur during the period when the wire current is sufficiently low during or immediately before suspension of the wire energization. This is made possible by defining a cycle of wire fusing by overheating and controlling in such a manner that the occurrence of fusing coincides with the start of the suspension of the wire energization.

Further, the method according to the present invention, in which the phenomenon of detachment of the filler wire 6 from the base metal 3 or the phenomenon that occurs during detachment of the filler wire 6 from the base metal 3 is detected electrically, is of course applicable, by changing the proportionality constant, to a control apparatus proposed by US 4 614 856 in which the heating power is controlled to produce a wire-heating power by measuring the power actually applied to the extension e̲ and controlling it to a value proportional to the feed rate of the wire 6. Although the resultant control apparatus is considerably complicated, the advantages are obtained that the response to a sudden change in the feed rate of the wire 6 or of the extension e̲ is further improved.

In a similar manner, power control is also possible by configuring a control circuit by which the square of the effective value of the wire-heating current is proportional to the wire feed rate and the proportionality constant thereof is changed in accordance with the method of the present invention. In this way, the response to an abrupt change in the extension e̲ of the filler wire 6 is performed by the means according to the present invention, and therefore is inferior to the response in the above-mentioned case. In spite of this, the response to the, change in wire feed rate remains superior as in the above-mentioned embodiment. The advantage in this case is that the need of detecting the wire voltage from a point very near to the ends of the extension e̲ in order to detect the wire-heating power in the U.S. Patent No. 4,614,856 described above, which is very troublesome in the welding work, is eliminated.

The present invention, of which description is made above with reference to a wire-heating power supply with a system using the triac 16, is not limited to such a method, but the invention is also applicable to a method using a power supply for a pulse energization heating system provided with a wire-heating current suspended for a given period of time. Fig. 10 shows the wire terminal voltage of a system using an inverter-type power supply as a second embodiment of the present invention. During section d̲ in Fig. 10, the steady welding work is proceeding with the wire 6 in contact with the base metal 3, and the voltage remains virtually zero during the wire current suspension. During the period j, the wire 6 is detached from the base metal 3, and during the wire current suspension period (f), the tip of the wire detects the potential in the arc plasma. When the detachment of the wire tip from the base metal according to this invention is detected, the energization at the next pulse period (during the section g) is interrupted, thereby preventing the disturbance of the arc.

The foregoing description concerns a method of control to keep the condition of almost proper heating power by causing complete overheating of the filler wire to the point of fusing. A frequent fusing accompanied by spattering, however, is not desirable. To obviate this, another method of control is proposed, in which the moment immediately before fusing is detected from a change in the wire current, the wire voltage or the output terminal voltage or the wire resistance value determined therefrom.

Fig. 11 shows a third embodiment of the wire-heating power supply and the control circuit 3 according to the present invention, in which a controller 26 for detecting the condition immediately before fusing is added to the wire-heating power supply and the control circuit included in Fig. 3.

In Fig. 11, the same reference numerals as in Fig. 3 designate the same component parts as in Fig. 3.

In Fig. 11, the controller 26, in response to an output signal Vc of a current differentiation sensor 27 for producing the differentiated waveform of the wire current Iw, detects the condition immediately before fusing from the change in the output signal Vc, and sends a firing signal to the gates of thyristors 28, 29 directly coupled to the secondary winding of the main transformer 15. At the same time, a signal Vd is applied to the on-off control circuit 22 thereby to suspend the energization of the triac 16 until the lapse of a predetermined time period. This predetermined time period t is set with reference to the signal Va from the wire contact condition detector circuit 21 as the time duration from re-contact of the wire 6 with the base metal 3, if away therefrom, or from the detection of the point immediately before fusing, if not away therefrom, until the wire 6 is fed by 0.5 mm. In this way, the output of the main transformer 15 is shunted into the thyristors 28 and 29 immediately before fusing, resulting in a sharp reduction in the output current, so that the overheated wire 6 is fused off sharply in a manner not to form any spatter. Energization is resumed with the wire 6 fully in contact in the molten pool, and the applied power involved is slightly reduced, thereby controlling the heating power in a manner similar to the above-mentioned case of fusing.

Fig. 12 shows the changes with time of the heating current Iw for the filler wire 6, the output terminal voltage Vw of the heating power supply, the current It flowing in the thyristor 28 and the output voltage Vc of the sensor 27 for producing the differentiated value of the wire current Iw for the apparatus shown in Fig. 11. At the time point a immediately before fusing by excessive heat, the resistance value of the filler wire 6 in the extension e is sharply increased due to the rise in the specific resistance with temperature increase and the reduction in the sectional area with the result that the wire current Iw sharply decreases, and at the same time a lower load reduces the voltage drop in the power supply, resulting in an increased output terminal voltage Vw.

The current waveform with the wire 6 energized in contact with the base metal 3 is shown by k in Fig. 12, and the differentiated waveform thereof is designated by numeral ℓ. When the wire 6 is almost near the fusing state by being overheated during energization, the wire current decreases at a considerably higher rate than under normal conditions. As a result, the differentiation waveform of the wire current detected by the current differentiation sensor 27, unlike the wire energization waveform 1 under normal conditions, takes the form of a sharp high level peak as shown by n. A comparator with a threshold level slightly higher than the output under normal conditions of the differentiation sensor 27 disposed in the fusing detection control circuit 26 is supplied with the signal output n, thereby easily detecting that the wire 6 is likely to be fusing.

In view of the fact that the wire resistance sharply increases causing a change in current and voltage in this way immediately before fusing, the condition immediately before fusing can be detected with considerable accuracy.

In Fig. 12 when it is detected that the condition immediately before fusing exists near the time point a, the energization of the wire is stopped at once. At this time the wire is retained to be in contact with the base metal 3, and the wire is detached from the base metal 3 at the time point b. As the wire is not energized at the time point b, no spatter is generated when the wire is detached from the base metal.

Actually, in the prior art, it takes 0.8 ms for the wire current to be reduced to zero from the fusing start. According to the third embodiment using the shorting of a thyristor by contrast, the wire current is reduced to zero within 0.1 ms after fusing start.

As explained above, according to the third embodiment of the present invention, the wire current is reduced to zero within a very short time as compared with the conventional method after wire fusion, and therefore the spatters, which otherwise are caused by fusing of the overheated wire 6, are extremely reduced. An advantage specific to the third embodiment is that the fused wire 6 brings the thyristor in to the conductive state, so that the energization continues till the zero cross point with a current waveform substantially similar to the normal waveform of the current flowing in the main transformer 15, after which the energization is inhibited at the primary triac 16 again before the tip of the wire 6 comes into contact with the base metal 3. As a result, the current imbalance between the positive and negative half waves of the current flowing in the main transformer 15 is further reduced, thereby leading to the advantage of lesser cases of magnetic polarization of the main transformer due to the DC components.

Fig. 13 shows a fourth embodiment of the wire-heating power supply and the control circuit according to the present invention. A triac 35 is connected to the secondary output terminal of a main transformer 15, and the secondary output immediately after fusing is shorted at the moment of the fusing to reduce the current supplied to the wire.

The present invention is not limited to the above-mentioned wire-heating power supply using a triac, but may be applied with equal effect to a wire-heating power supply of inverter type, etc., using a transistor.

As a fifth embodiment of the present invention, Fig. 14 shows an example of the wire current waveform Iw and the output voltage waveform Vw of a circuit of inverter type used as a wire-heating power supply. These waveforms are basically similar to square waves, and the wire current is reduced considerably rapidly at the time of fusing of the energized and over-heated wire. Therefore, it is also possible to detect the moment nearly before the fusing easily from the differentiated current waveform, thus making it possible to dc-energize the wire 6 promptly by use of the primary transistor for high-speed switching such as at 20 kHz. In spite of the periodical reduction in current due to a pulse current form, the normal pulse current form is not affected at all even if the periodical reduction is detected erroneously as an overheated fusing signal.

Apart from the foregoing description of the detection of fusing by overheating of the wire 6 from a differentiated waveform of the wire current, a similar detection is also possible from the change in the wire voltage Vw as shown in Fig. 14 in the case where the wire current takes a form similar to a square wave like in the inverter power supply. Specifically, when the secondary current decreases with approaching fusing by overheating, the voltage drop in the heating power supply and in the power cables decreases, and the secondary output terminal voltage of the power supply rises, so that detection is possible from a change in the differentiated or absolute value of the output voltage immediately before or at the moment of fusing.

Also, the invention may be embodied in a filler wire heating power supply producing a continuous AC current or continuous DC current which so far has been commonly used for the hot-wire welding process. As still another alternative, a filler wire-heating power supply for producing an AC pulse current may be also used.

Instead of the above-mentioned combination of the hot-wire heating power supply with the TIG arc for hot-wire TIG arc welding process, the present invention may be applied also to a hot-wire welding process combining a consumable electrode arc for the hot-wire welding process in which spatter does not damage the electrode, thus substantially eliminating spatters from the hot wire.

The wire terminal voltage Vw, which is generally detected between the base metal 3 and a contact tip for energizing the wire 6, may alternatively be detected as the output terminal voltage of the wire-heating power supply.

It will thus be understood from the foregoing description that according to the present invention, manual operation is substantially eliminated for keeping an optimum wire-heating power in the hot-wire welding process. More specifically, a proper wire-heating power can be stably and automatically maintained regardless of changes in such conditions as welding factors for the hot-wire welding process including arc current, arc length, material or shape or feed rate of the filler wire, extension or the position or angle of insertion into the molten pool. As a consequence, the disadvantage of the hot-wire TIG welding process in which an unmolten wire liable to be formed remains in the weld metal is completely eliminated. Further, a proper heating power is kept automatically by matching these various changes in the welding conditions, thereby greatly facilitating the semi-automatic hot-wire welding operation which has so far encountered considerable difficulties.

Further, in the prior art control system for supplying the wire-heating power corresponding to the wire feed rate, a power detection device comprising a Hall element or the like for detecting the wire heating, power in addition to a wire feed rate detector are required, and also, it is necessary to detect the wire voltage by such a detector placed as near to the ends of the extension as possible to determine the heating power as accurate as possible, thereby complicating the wiring work for the welding process. In many embodiments of the present invention, in contrast, a detection of the wire-heating power is not required, but it is only necessary to detect the output terminal voltage of the wire-heating power supply in place of the voltage across the extension, thus greatly simplifying the contol device and reducing it's cost.

Furthermore, according to the present invention, a proper wire-heating power is maintained fully automatically, and spatters are virtually eliminated, thereby making possible a continuous hot-wire welding over long time periods.

Claims

1. A method of welding control for a hot-wire welding apparatus comprising an arc power supply (4), an arc electrode (2) connected to said arc power supply (4), a filler wire (6) leading to a molten pool (11), and a wire-heating power supply (10) for heating by energization of the filler wire (6), wherein a pulse-like direct or alternating current is applied to the filler wire (6), and, during the de-energizing period of the pulse current, it is detected whether or not the filler wire (6) is in contact with the molten pool (11), and the current applied to the filler wire (6) is inhibited during the subsequent energizing period when it has been detected that the filler wire (6) is not in contact with the molten pool (11).

2. A method of welding control for a hot-wire welding apparatus comprising an arc power supply (4), an arc electrode (2) connected to said arc power supply (4), a filler wire (6) leading to a molten pool (11), and a wire-heating power supply (10) for heating by energization of the filler wire (6), wherein the heating power is increased until the filler wire (6) is fused, and the wire heating power after fusing the filler wire (6) under excessive heat is set lower than the heating power immediately before the fusing of the filler wire (6), and the wire-heating power is again gradually increased from the lower setting until the filler wire (6) is again fused under excessive heat.

3. A hot-wire welding apparatus comprising an arc power supply (4), an arc electrode (2) connected to the arc power supply (4), a filler wire (6) leading to a molten pool (11), a wire-heating power supply (10) for heating by energization of the filler wire (6), a control circuit (19) for controlling the heating power applied to the filler wire (6), which produces a pulse-like direct or alternating current, and a wire contact detector circuit (21) which electrically detects during the de-energizing periods of the pulse current whether or not the filler wire (6) is in contact with the molten pool (11), and wherein the control circuit (19) inhibits the current applied to the filler wire (6) during the subsequent energizing period when it has been detected that the filler wire is not in contact with the molten pool (11).

4. A hot-wire welding apparatus comprising an arc power supply (4), an arc electrode (2) connected to the arc power supply (4), a filler wire (6) leading to a molten pool (11), a wire-heating power supply (10) for heating by energization of the filler wire (6) and a control circuit (19) for controlling the heating power applied to the filler wire (6) such that the heating power is increased until the filler wire (6) is fused, and the wire heating power after fusing the filler wire (6) under excessive heat is set lower than the heating power immediately before the fusing of the filler wire (6), and the wire-heating power is again gradually increased from the lower setting until the filler wire (6) is again fused under excessive heat.

5. The hot-wire welding apparatus according to claim 4, wherein the power supply (10) produces a pulse-like direct current or a pulse-like alternating current.

6. The hot-wire welding apparatus according to claim 5, further comprising
a wire contact detector circuit (21) including
a terminal voltage detecting circuit (213) for detecting, during a de-energizing period of the pulse current, the terminal voltage of the filler wire (6) or the output terminal voltage of the wire heating power supply (10), and
a comparator circuit (214) for comparing the detected voltage from the terminal voltage detecting circuit (213) with a predetermined reference voltage (215) to detect whether or not the filler wire (6) is in contact with the molten pool (11) during the de-energizing period of the pulse current, so that when the filler wire (6) is not in contact with the molten pool (11) during the de-energizing period of the pulse current, a signal is put out to inhibit the energization during the energizing period of the pulse current immediately following the de-energizing period of the pulse current.

7. The hot-wire welding apparatus according to claim 4, further comprising
a wire contact detector circuit (21) for electrically detecting a contact condition of the filler wire (6) with the molten pool (11), and
a circuit (23) for controlling the heating power supplied-to the filler wire (6) so that when the wire contact detector circuit (21) generates a signal indicating a transition from the contact condition to a wire separated condition, the heating power supplied to the filler wire (6) is decreased, and when the wire contact detection circuit (21) generates a signal indicating that the filler wire is in contact with the molten pool (11), the heating power supplied to the filler wire (6) is gradually increased.

8. The hot-wire welding apparatus according to claim 5 or 6, further comprising a fusing detector circuit (34) for detecting a process of fusing of the filler wire (6) by heat during an energizing period of the filler wire (6), wherein the control circuit (19) instantly and rapidly reduces the wire current or stops the energization for the pulse period of the pulse current on the basis of a fusing detection signal from said fusing detector circuit (34).

9. The hot-wire welding apparatus according to claim 8, wherein the fusing detector circuit (34) is adapted to detect the fusing process of the filler wire (6) from a change in the differentiated waveform of the wire current.

10. The hot-wire welding apparatus according to claim 8, wherein the fusing detector circuit (34) is adapted to detect the process of fusing of the filler wire (6) from a change in the wire voltage waveform.

11. The hot-wire welding apparatus according to one of claims 4 to 10, further comprising a circuit including a semiconductor switching element (28, 29, 35) connected in parallel to the filler wire (6), wherein the energization current for the filler wire (6) is sharply reduced by shunting the current with the semiconductor switching element (28, 29, 35) turned on.

12. The hot-wire welding apparatus according to one of claims 6 to 11, further comprising a controller (26) for reducing the energization current for the filler wire (6) by shunting, and either for restarting the wire energization after a predetermined period following the detecting that the wire has come into contact with the base metal again during the de-energization period of pulse current, or for restarting the wire energization after feeding a predetermined amount of the filler wire (6) following the detection that the filler wire has come into contact with the base metal during the pulsed current deenergization period of the pulsed current.

13. The hot-wire welding apparatus according to one of claims 6 to 12, wherein the power supply (10) produces a pulsed current on the basis of a control signal from a circuit (212) for determining a wire de-energization period.

14. The hot-wire welding apparatus according to one of claims 6 to 13, further comprising a circuit (23) for forming a reference time interval, and wherein the control circuit (10) increases the increase rate of the wire-heating-power, when the time interval of signals from the fusing detector circuit (34) and/or the wire contact detector circuit (21) is longer than a reference time interval, and reduces the increase rate of the wire-heating power when said time interval is shorter than the reference time interval.

15. The hot-wire welding apparatus according to one of claims 6 to 13, further comprising a circuit (23) for forming a reference time interval, and wherein the control circuit (10) increases the wire-heating power by a predetermined amount when the time interval of signals from the fusing detector circuit (34) and/or the wire contact detector circuit (21) is longer than the reference time interval, and reduces the wire-heating power by a predetermined amount when said time interval is shorter than the reference time interval.

16. The hot-wire welding apparatus according to one of claims 6 to 13, further comprising a circuit (23) for producing a signal corresponding to the wire-heating power and the square of the effective value of the wire current in proportion to the wire feed rate, and wherein the control circuit (10) controls the power applied to the filler wire (6) by regulating the proportionality constant thereof.

17. The hot-wire welding apparatus according to one of claims 6 to 16, wherein:

- the control circuit (19) comprises a semiconductor switching element (16);
- a setting circuit (24) is provided for setting a voltage ramping rate and a voltage reduction margin;
- the circuit (23) receives a signal from the wire contact detector circuit (21) and a voltage from the setting circuit (24), and puts out a voltage (V_b) to the control circuit (10) for controlling the energization period of the pulse current, and
- the control circuit (10) comprises a pulse forming circuit (20) receiving a signal (V_a) from the wire contact detector circuit (21) and the voltage (V_b) from the circuit (23), for controlling the energizing period of the wire heating pulse current by operating the switching element (16) in proportion to the voltage from the circuit (23) when the wire contact detector circuit (21) generates the contact signal, and for inhibiting energization of the filler wire (6) for a predetermined period and restarting the wire energization thereafter by operating the switching element (16) when the wire contact detector circuit (21) generates the non-contact signal.

18. The hot-wire welding apparatus according to one of claims 12 to 17, comprising
a current differentiation sensor (27) for detecting the wire current and for putting out a signal (V_c) of the differentiated waveform of the wire current (I_w), and
a controller (26) which receives the signal (V_c) from the current differentiation sensor (27), for detecting the wire condition immediately before fusing and rapidly decreases the wire heating current of the control circuit (19).

Patentansprüche

1. verfahren zur Überwachung des Schweißens bei einem Heißdrahtschweißgerät mit einer Lichtbogenstromversorgung (4), einer Lichtbogenelektrode (2), die mit der Lichtbogenstromversorgung (4) verbunden ist, einem Zusatzdraht (6), der zu einem Schweißbad (11) führt, und einer Drahtheizstromversorgung (10) zum Erhitzen des Zusatzdrahts (6) durch elektrische Erregung, wobei ein pulsförmiger Gleich- oder Wechselstrom an den Zusatzdraht (6) angelegt wird, und wobei während des Entregungszeitraums des gepulsten Stroms erfaßt wird, ob der Zusatzdraht (6) in Kontakt mit dem Schweißbad (11) ist oder nicht, und der an den Zusatzdraht (6) angelegte Strom während der nachfolgenden Erregungsperiode gesperrt wird, wenn erfaßt worden ist, daß der Zusatzdraht (6) nicht in Kontakt mit dem Schweißbad (11) ist.

2. Verfahren zur Überwachung des Schweißens bei einem Heißdrahtschweißgerät mit einer Lichtbogenstromversorgung (4), einer Lichtbogenelektrode (2), die mit der Lichtbogenstromversorgung (4) verbunden ist, einem Zusatzdraht (6), der zu einem Schweißbad (11) führt, und einer Drahtheizstromversorgung (10) zum Erhitzen des Zusatzdrahts (6) durch elektrische Erregung, wobei die Heizleistung erhöht wird, bis der Zusatzdraht (6) schmilzt, und die Drahtheizleistung nach dem Schmelzen des Zusatzdrahts (6) unter übermäßiger Hitze kleiner als die Heizleistung unmittelbar vor dem Schmelzen des Zusatzdrahts (6) eingestellt wird, und die Drahtheizleistung wieder allmählich von dem niedrigeren Einstellwert aus erhöht wird, bis der Zusatzdraht (6) wieder unter übermäßiger Hitze schmilzt.

3. Heißdrahtschweißgerät mit einer Lichtbogenstromversorgung (4), einer Lichtbogenelektrode (2), die mit der Lichtbogenstromversorgung (4) verbunden ist, einem Zusatzdraht (6), der zu einem Schweißbad (11) führt, einer Drahtheizstromversorgung (10) zum Erhitzen des Zusatzdrahts (6) durch elektrische Erregung, einer Steuerschaltung (19) zum Steuern der an den Zusatzdraht (6) angelegten Heizleistung, die einen pulsförmigen Gleich- oder Wechselstrom erzeugt, und einer Drahtkontakterfassungsschaltung (21), die während der Entregungszeiträume des Pulsstroms elektrisch erfaßt, ob der Zusatzdraht (6) mit dem Schweißbad (11) in Kontakt ist oder nicht, und wobei die Steuerschaltung (19) den an den Zusatzdraht (6) angelegten Strom während des nachfolgenden Erregungszeitraums sperrt, wenn erfaßt worden ist, daß der Zusatzdraht nicht in Kontakt mit dem Schweißbad (11) ist.

4. Heißdrahtschweißgerät mit einer Lichtbogenstromversorgung (4), einer Lichtbogenelektrode (2), die mit der Lichtbogenstromversorgung (4) verbunden ist, einem Zusatzdraht (6), der zu einem Schweißbad (11) führt, einer Drahtheizstromversorgung (10) zum Erhitzen des Zusatzdrahts (6) durch elektrische Erregung und einer Steuerschaltung (19) zum Steuern der an den Zusatzdraht (6) angelegten Heizleistung so, daß die Heizleistung erhöht wird, bis der Zusatzdraht (6) schmilzt und die Drahtheizleistung nach dem Schmelzen des Zusatzdrahts (6) unter übermäßiger Hitze niedriger als die Heizleistung unmittelbar vor dem Schmelzen des Zusatzdrahts (6) eingestellt wird, und die Drahtheizleistung wieder allmählich von dem niedrigeren Einstellwert aus erhöht wird, bis der Zusatzdraht (6) wieder unter übermäßiger Hitze schmilzt.

5. Heißdrahtschweißgerät nach Anspruch 4, bei dem die Stromversorgung (10) einen pulsförmigen Gleichstrom oder einen pulsförmigen Wechselstrom erzeugt.

6. Heißdrahtschweißgerät nach Anspruch 5, zusätzlich mit
einer Drahtkontaktdetektorschaltung (21) mit
einer Anschlußspannungserfassungsschaltung (213) zum Erfassen der Anschlußspannung des Zusatzdrahts (6) oder der Ausgangsanschlußspannung der Drahtheizstromversorgung (10) während eines Entregungszeitraums des pulsförmigen Stroms, und
einer Komparatorschaltung (214) zum Vergleichen der von der Anschlußspannungserfassungsschaltung (213) erfaßten Spannung mit einer vorbestimmten Bezugsspannung (215), um während des Entregungszeitraums des pulsförmigen Stroms zu erfassen, ob der Zusatzdraht (6) in Kontakt mit dem Schweißbad (11) ist oder nicht, so daß, wenn der Zusatzdraht (6) nicht in Kontakt mit dem Schweißbad (11) während des Entregungszeitraums des pulsför migen Stroms ist, ein Signal ausgegeben wird, um die Erregung während des unmittelbar auf den Entregungszeitraum des pulsförmigen Stroms folgenden Erregungszeitraums des pulsförmigen Stroms zu sperren.

7. Heißdrahtschweißgerät nach Anspruch 4, ferner mit
einer Drahtkontakterfassungsschaltung (21) zum elektrischen Erfassen eines Kontaktzu-

stands des Zusatzdrahts (6) mit dem Schweißbad (11) und
einer Schaltung (23) zum Steuern der an den Zusatzdraht (6) angelegten Heizleistung, so daß, wenn die Drahtkontakterfassungsschaltung (21) ein Signal erzeugt, das einen Übergang vom Kontaktzustand in einen Zustand mit kontaktlosem Draht anzeigt, die dem Zusatzdraht (6) zugeführte Heizleistung verringert wird, und wenn die Drahtkontakterfassungsschaltung (21) ein Signal erzeugt, das anzeigt, daß der Zusatzdraht in Kontakt mit dem Schweißbad (11) ist, die dem Zusatzdraht (6) Zugeführte Heizleistung allmählich erhöht wird.

8. Heißdrahtschweißgerät nach Anspruch 5 oder 6, ferner mit einer Schmelzerfassungsschaltung (34) zum Erfassen eines Schmelzvorgangs des Zusatzdrahts (6) durch Hitze während eines Erregungszeitraums des Zusatzdrahts (6), wobei die Steuerschaltung (19) auf der Grundlage eines Schmelzerfassungssignals von der Schmelzerfassungsschaltung (34) den Drahtstrom instantan und schnell verringert oder die Erregung während des Pulszeitraums des pulsförmigen Stroms beendet.

9. Heißdrahtschweißgerät nach Anspruch 8, bei dem die Schmelzerfassungsschaltung (34) eingerichtet ist, um den Schmelzprozeß des Zusatzdrahts (6) aus einer Änderung der differenzierten Schwingungsform des Drahtstroms zu erfassen.

10. Heißdrahtschweißgerät nach Anspruch 8, bei dem die Schmelzerfassungsschaltung (34) eingerichtet ist, um den Schmelzvorgang des Zusatzdrahts (6) aus einer Änderung der Schwingungsform der Drahtspannung zu erfassen.

11. Heißdrahtschweißgerät nach einem der Ansprüche 4 bis 10, ferner mit einer Schaltung, die ein parallel zum Zusatzdraht (6) geschaltetes Halbleiterschaltelement (28, 29, 35) enthält, wobei der Erregungsstrom für den Zusatzdraht (6) scharf reduziert wird, indem der Strom bei eingeschaltetem Halbleiterschaltelement (28, 29, 35) geshuntet wird.

12. Heißdrahtschweißgerät nach einem der Ansprüche 6 bis 11, ferner mit einer Steuerung (26) zum Verringern des Erregungsstroms für den Zusatzdraht (6) durch Shunten, und entweder zum Neustarten der Drahterregung nach einem vorgegebenen Zeitraum nach der Erfassung, daß der Draht während des Entregungszeitraums des pulsförmigen Stroms wieder in Kontakt mit dem Basismetall gekommen ist, oder zum Neustarten der Drahterregung nach dem Zuführen einer vorgegebenen Menge von Zusatzdraht (6), nach der Erfassung, daß der Zusatzdraht während des Entregungszeitraums des pulsförmigen Stroms in Kontakt mit dem Basismetall gekommen ist.

13. Heißdrahtschweißgerät nach einem der Ansprüche 6 bis 12, bei dem die Stromversorgung (10) einen pulsförmigen Strom auf der Grundlage eines Steuersignals von einer Schaltung (212) zum Bestimmen eines Drahtentregungszeitraums erzeugt.

14. Heißdrahtschweißgerät nach einem der Ansprüche 6 bis 13, ferner mit einer Schaltung (23) zum Erzeugen eines Bezugszeitintervalls, und bei dem die Steuerschaltung (10) die Zunahmegeschwindigkeit der Drahtheizleistung erhöht, wenn das Zeitintervall der Signale von der Schmelzerfassungsschaltung (34) und/oder der Drahtkontakterfassungsschaltung (21) länger als ein Bezugszeitintervall ist, und die Zunahmegeschwindigkeit der Drahtheizleistung verringert, wenn das Zeitintervall kürzer als das Bezugszeitintervall ist.

15. Heißdrahtschweißgerät nach einem der Ansprüche 6 bis 13, ferner mit einer Schaltung (23) zum Erzeugen eines Bezugszeitintervalls, und bei dem die Steuerschaltung (10) die Drahtheizleistung um einen vorgegebenen Betrag erhöht, wenn das Zeitintervall der Signale von der Schmelzerfassungsschaltung (34) und/oder der Drahtkontakterfassungsschaltung (21) länger als das Bezugszeitintervall ist, und die Drahtheizleistung um einen vorgegebenen Betrag verringert, wenn dieses Zeitintervall kürzer als das Bezugszeitintervall ist.

16. Heißdrahtschweißgerät nach einem der Ansprüche 6 bis 13, ferner mit einer Schaltung (23) zum Erzeugen eines Signals, das der Drahtheizleistung und dem Quadrat des Effektivwerts des Drahtstroms in Proportion zur Drahtzufuhrgeschwindigkeit entspricht, und bei dem die Steuerschaltung (10) die an den Zusatzdraht (6) angelegte Leistung durch Regeln von dessen Proportionalitätskonstante steuert.

17. Heißdrahtschweißgerät nach einem der Ansprüche 6 bis 16, bei dem:
- die Steuerschaltung (19) ein Halbleiterschaltelement (16) umfaßt;
- eine Einstellschaltung (24) vorgesehen ist, um eine Spannungsrampengeschwindigkeit und eine Spannungsverringerungsschwelle einzustellen;

- die Schaltung (23) ein Signal von der Drahtkontakterfassungsschaltung (21) und eine Spannung von der Einstellschaltung (24) empfängt und eine Spannung (V_b) an die Steuerschaltung (10) zum Steuern des Erregungszeitraums des pulsförmigen Stroms ausgibt, und
- die Steuerschaltung (10) eine Pulsformerschaltung (20) umfaßt, die ein Signal (V_a) von der Drahtkontakterfassungsschaltung (21) und die Spannung (V_b) von der Schaltung (23) empfängt, um den Erregungszeitraum des pulsförmigen Drahtheizstroms durch Betätigen des Schaltelements (16) in Proportion zur Spannung von der Schaltung (23) zu betätigen, wenn die Drahtkontakterfassungsschaltung (21) das Kontaktsignal erzeugt, und um die Erregung des Zusatzdrahts (6) für einen vorgegebenen Zeitraum zu sperren und die Drahterregung danach durch Betätigen des Schaltelements (16) neu zu starten, wenn die Drahtkontakterfassungsschaltung (21) das Nichtkontaktsignal erzeugt.

18. Heißdrahtschweißgerät nach einem der Ansprüche 12 bis 17, mit
einem Stromdifferenzierungssensor (27) zum Erfassen des Drahtstroms und zum Ausgeben eines Signals (V_c) der differenzierten Schwingungsform des Drahtstroms (I_w), und
einer Steuerung (26), die das Signal (V_c) vom Stromdifferenzierungssensor (27) empfängt, um den Drahtzustand unmittelbar vor dem Schmelzen zu erfassen, und die den Drahtheizstrom der Steuerschaltung (19) schnell verringert.

Revendications

1. Procédé de réglage de soudage destiné à un appareil de soudage à fil chaud comprenant une alimentation (4) de formation d'un arc, une électrode (2) de formation d'un arc, raccordée à l'alimentation (4), un fil de remplissage (6) rejoignant une mare fondue (11) et une alimentation (10) de chauffage de fil destinée à assurer le chauffage par excitation du fil de remplissage (6), dans lequel un courant continu pulsé ou alternatif est appliqué au fil de remplissage (6) et, pendant la période de désexcitation du courant pulsé, le fait que le fil de remplissage (6) est au contact de la mare fondue (11) ou non est détecté, et le courant appliqué au fil de remplissage (6) est arrêté pendant la période suivante d'excitation lorsqu'il a été détecté que le fil de remplissage (6) n'est pas au contact de la mare fondue (11).

2. Procédé de réglage de soudage destiné à un appareil de soudage à fil chaud comprenant une alimentation (4) de formation d'un arc, une électrode (2) de formation d'un arc connectée à l'alimentation (4), un fil de remplissage (6) rejoignant une mare fondue (11), et une alimentation (10) de chauffage de fil destinée à assurer un chauffage par excitation du fil de remplissage (6), dans lequel la puissance de chauffage est augmentée jusqu'à ce que le fil de remplissage (6) soit fondu, et la puissance de chauffage du fil, après la fusion du fil de remplissage (6) par une quantité excessive de chaleur, est réglée à une valeur inférieure à la valeur de la puissance de chauffage précédant immédiatement la fusion du fil de remplissage (6), et la puissance de chauffage du fil est à nouveau augmentée progressivement à partir du réglage inférieur jusqu'à ce que le fil de remplissage soit à nouveau fondu par une quantité excessive de chaleur.

3. Appareil de soudage à fil chaud comprenant une alimentation (4) de formation d'arc, une électrode (2) de formation d'arc connectée à l'alimentation (4), un fil de remplissage (6) rejoignant une mare fondue (11), une alimentation (10) de chauffage de fil destinée à chauffer par excitation le fil de remplissage (6), un circuit (19) de réglage de la puissance de chauffage appliquée au fil de remplissage (6), qui forme un courant alternatif ou continu analogue à un courant pulsé, et un circuit (21) détecteur de contact du fil qui détecte électriquement, pendant les périodes de désexcitation du courant pulsé, si le fil de remplissage (6) est au contact de la mare fondue (11) ou non, et dans lequel le circuit de réglage (19) empêche l'application du courant au fil de remplissage (6) pendant la période suivante d'excitation lorsqu'il a été détecté que le fil de remplissage n'est pas au contact de la mare fondue (11).

4. Appareil de soudage à fil chaud comprenant une alimentation (4) destinée à former un arc, une électrode (2) destinée à former un arc et raccordée à l'alimentation (4), un fil de remplissage (6) rejoignant une mare fondue (11), une alimentation (10) de chauffage de fil destinée à chauffer par excitation du fil de remplissage (6), et un circuit (19) de réglage de la puissance de chauffage appliquée au fil de remplissage (6) afin que la puissance de chauffage soit augmentée jusqu'à la fusion du fil de remplissage (6), et la puissance de chauffage du fil, après fusion du fil de remplissage (6) par un excès de chaleur, est réglée à une valeur inférieure à la puissance de chauffage immédiatement avant la fusion du fil de remplissage (6), la puissance de chauffage du fil est à nouveau augmentée progressivement depuis le réglage inférieur jusqu'à ce que le fil de remplissage (6) soit à nouveau fondu par une quantité excessive de chaleur.

5. Appareil de soudage à fil chaud selon la revendication 4, dans lequel l'alimentation (10) produit un courant alternatif analogue à des impulsions ou un courant continu analogue à des impulsions.

6. Appareil de soudage à fil chaud selon la revendication 5, comprenant en outre

un circuit (21) détecteur de contact du fil qui comporte

un circuit (213) de détection d'une tension aux bornes destiné à détecter, pendant la période de nouvelle excitation du courant pulsé, la tension aux bornes du fil de remplissage (6) ou la tension aux bornes de sortie de l'alimentation (10) de chauffage de fil, et

un circuit comparateur (214) destiné à comparer la tension détectée provenant du circuit (213) de détection de tension aux bornes à une tension prédéterminée de référence (215) pour la détection du fait que le fil de remplissage (6) est au contact de la mare fondue (11) ou non pendant la période de désexcitation du courant pulsé, si bien que, lorsque le fil de remplissage (6) n'est pas au contact de la mare fondue (11) pendant la période de défaut d'excitation du courant pulsé, un signal est transmis pour l'interdiction de l'excitation pendant la période d'excitation du courant pulsé suivant immédiatement la période de désexcitation du courant pulsé.

7. Appareil de soudage à fil chaud selon la revendication 4, comprenant en outre

un circuit (21) détecteur de contact du fil destiné à détecter électriquement une condition de contact entre le fil de remplissage (6) et la mare fondue (11), et

un circuit (23) de réglage de la puissance de chauffage transmise au fil de remplissage (6) afin que, lorsque le circuit (21) détecteur du contact du fil crée un signal indiquant une transition de l'état de contact à l'état de séparation du fil, la puissance de chauffage transmise au fil de remplissage (6) soit réduite et que, lorsque le circuit (21) de détection de contact de fil crée un signal indiquant que le fil de remplissage est au contact de la mare fondue (11), la puissance de chauffage transmise au fil de remplissage (6) soit progressivement accrue.

8. Appareil de soudage à fil chaud selon la revendication 5 ou 6, comprenant en outre un circuit (34) détecteur de fusion destiné à détecter la fusion du fil de remplissage (6) par la chaleur pendant une période d'excitation du fil de remplissage (6), et le circuit de réglage (19) réduit instantanément et rapidement le courant du fil ou interrompt l'excitation pendant la période d'impulsion du courant pulsé en fonction du signal de détection de fusion provenant du circuit (34) détecteur de fusion.

9. Appareil de soudage à fil chaud selon la revendication 8, dans lequel le circuit (34) détecteur de fusion est destiné à détecter la fusion du fil de remplissage (6) à partir d'un changement de la forme d'onde différentiée du courant du fil.

10. Appareil de soudage à fil chaud selon la revendication 8, dans lequel le circuit (34) détecteur de fusion est destiné à détecter l'opération de fusion du fil de remplissage (6) à partir d'un changement de la forme d'onde de tension du fil.

11. Appareil de soudage à fil chaud selon l'une quelconque des revendications 4 à 10, comprenant en outre un circuit contenant un élément de commutation à semiconducteur (28, 29, 35) connecté en parallèle avec le fil de remplissage (6), et dans lequel le courant d'excitation du fil de remplissage (6) est réduit nettement par mise en shunt du courant par fermeture de l'élément de commutation à semi-conducteur (28, 29, 35).

12. Appareil de soudage à fil chaud selon l'une des revendications 6 à 11, comprenant en outre un organe (26) de réglage destiné à réduire le courant d'excitation du fil de remplissage (6) par mise en shunt, et à recommencer l'excitation du fil après une période prédéterminée suivant la détection du fait que le fil est venu à nouveau au contact du métal de base pendant la période de désexcitation du courant pulsé, ou à recommencer l'excitation du fil après l'avance d'une quantité prédéterminée du fil de remplissage (6) suivant la détection du fait que le fil de remplissage est venu au contact du métal de base pendant la période de désexcitation du courant pulsé.

13. Appareil de soudage à fil chaud selon l'une des revendications 6 à 12, dans lequel l'alimentation (10) produit un courant pulsé d'après un signal de commande d'un circuit (212) destiné à déterminer une période de désexcitation du fil.

14. Appareil de soudage à fil chaud selon l'une des revendications 6 à 13, comprenant en outre un circuit (23) destiné à former un intervalle de temps de référence, et dans lequel le circuit de commande (10) augmente la vitesse d'accroissement de la puissance de chauffage du fil lorsque l'intervalle de temps des signaux provenant du circuit détecteur de fusion (34) et/ou du circuit détecteur de contact du fil (21) est supérieur à un intervalle de temps de référence, et réduit la vitesse d'augmentation de la puissance de chauffage du fil lorsque cet intervalle de temps est inférieur à l'intervalle de temps de référence.

15. Appareil de soudage à fil chaud selon l'une des revendications 6 à 13, comprenant en outre un circuit (23) destiné à former un intervalle de temps de référence, et dans lequel le circuit (10) de réglage augmente la puissance de chauffage du fil d'une quantité prédéterminée lorsque l'intervalle de temps des signaux provenant du circuit détecteur de fusion (34) et/ou du circuit détecteur de contact (21) est supérieur à l'intervalle de temps de référence, et réduit la puissance de chauffage du fil d'une quantité prédéterminée lorsque l'intervalle de temps est inférieur à l'intervalle de temps de référence.

16. Appareil de soudage à fil chaud selon l'une des revendications 6 à 13, comprenant en outre un circuit (23) destiné à produire un signal qui correspond à la puissance de chauffage du fil et au carré de la valeur efficace du courant du fil proportionnellement à la vitesse d'avance du fil, et dans lequel le circuit de réglage (10) règle la puissance appliquée au fil de remplissage (6) par régulation de la constante de proportionnalité correspondante.

17. Appareil de soudage à fil chaud selon l'une des revendications 6 à 16, dans lequel :

- le circuit (19) de réglage comporte un élément de commutation à semi-conducteur (16),
- un circuit (24) de consigne est destiné à régler une vitesse de variation progressive de tension et une marge de réduction de tension,
- le circuit (23) reçoit un signal du circuit détecteur de contact du fil (21) et une tension du circuit de consigne (24) et transmet une tension (V_b) au circuit (10) de réglage de la période d'excitation du courant pulsé, et
- le circuit de réglage (10) comprend un circuit formateur d'impulsions (20) qui reçoit un signal (V_a) du circuit détecteur de contact de fil (21) et la tension (V_b) du circuit (23) est destinée à régler la période d'excitation du courant pulsé de chauffage du fil par commande de l'élément de commutation (16) proportionnellement à la tension provenant du circuit (23) lorsque le circuit détecteur de contact du fil (21) crée le signal de contact, et à empêcher l'excitation du fil de remplissage (6) pendant une période prédéterminée et à recommencer ensuite l'excitation du fil par commande de l'élément de commutation (16) lorsque le circuit détecteur de contact du fil (21) crée le signal de défaut de contact.

18. Appareil de soudage à fil chaud selon l'une des revendications 12 à 17, comprenant

un capteur (27) de dérivation de courant destiné à détecter le courant dans le fil et à transmettre un signal (V_c) de la forme d'onde différentiée du courant dans le fil (I_w), et

un organe (26) de réglage qui reçoit le signal (V_c) du capteur de dérivation de courant (27) et destiné à détecter la condition du fil juste avant la fusion et à réduire rapidement le courant de chauffage du fil du circuit de réglage (19).

FIG. 1
PRIOR ART

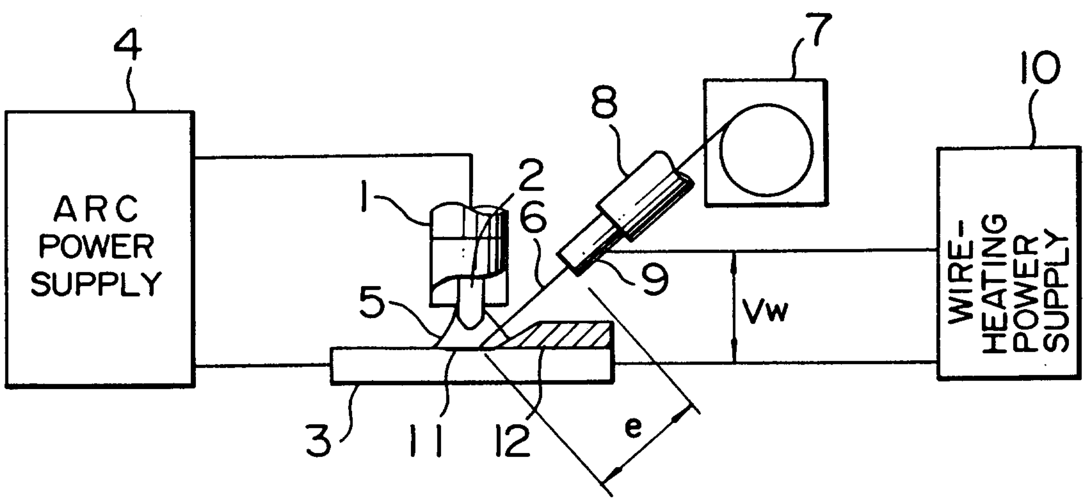

FIG. 2
PRIOR ART

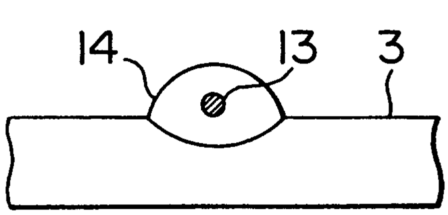

FIG. 3

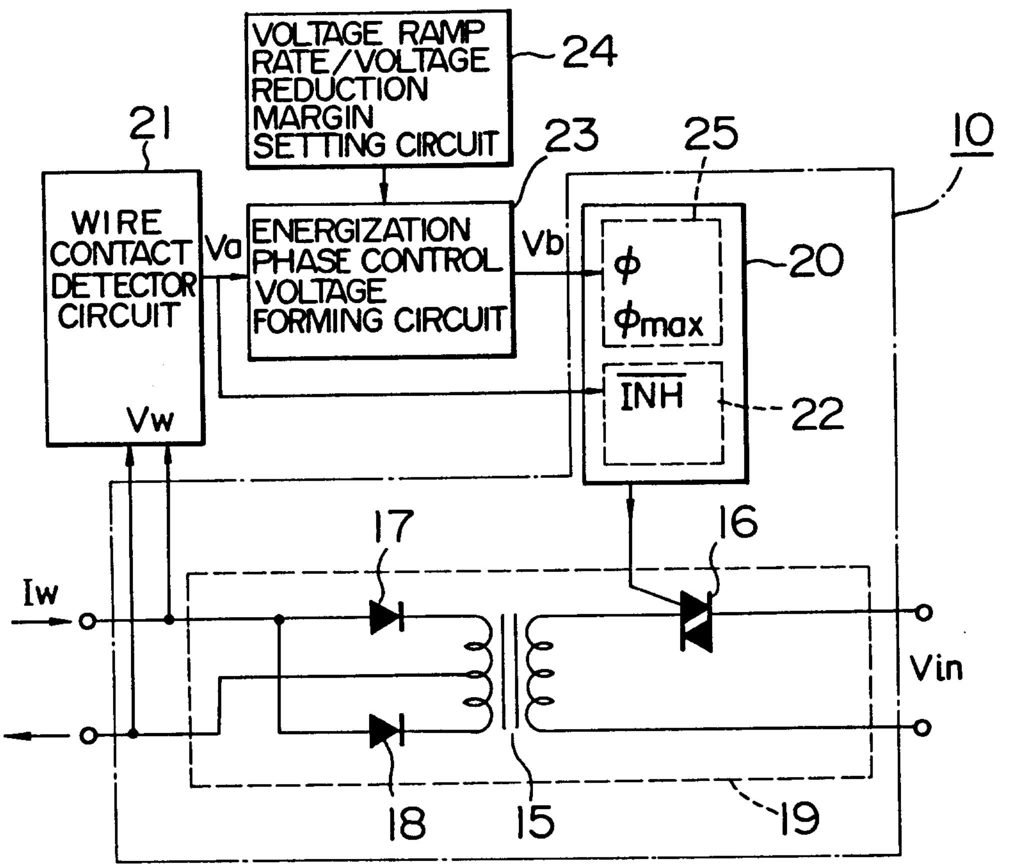
VOLTAGE RAMP RATE/VOLTAGE REDUCTION MARGIN SETTING CIRCUIT
24
21
23
25
10
WIRE CONTACT DETECTOR CIRCUIT
Va
ENERGIZATION PHASE CONTROL VOLTAGE FORMING CIRCUIT
Vb
φ
φmax
20
INH
22
Vw
17
16
Iw
Vin
18
15
19

FIG. 4

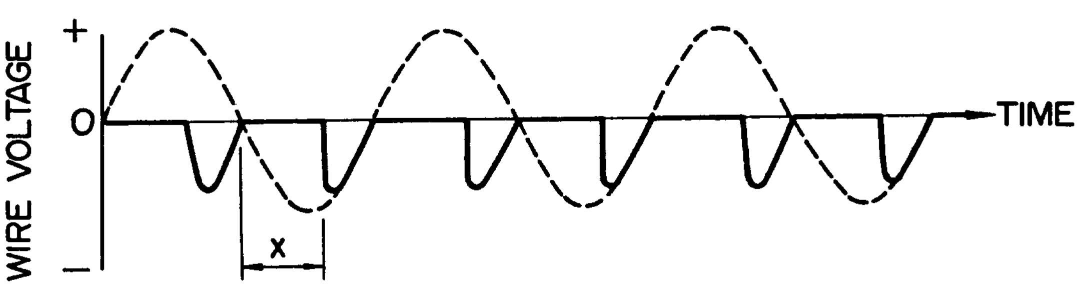
WIRE VOLTAGE
+
O
TIME
x
−

FIG. 5

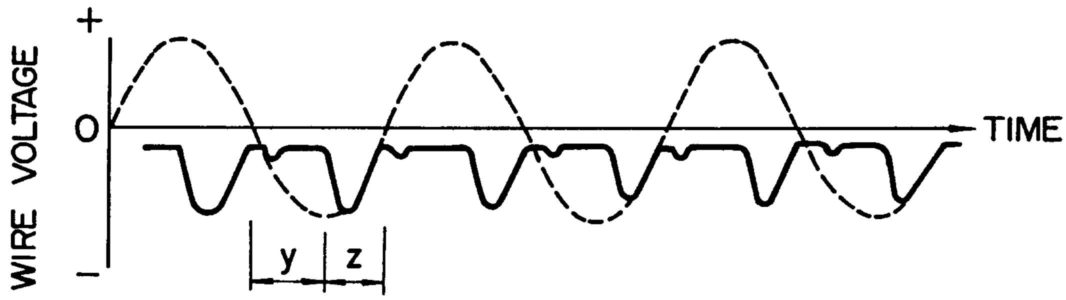

FIG. 6

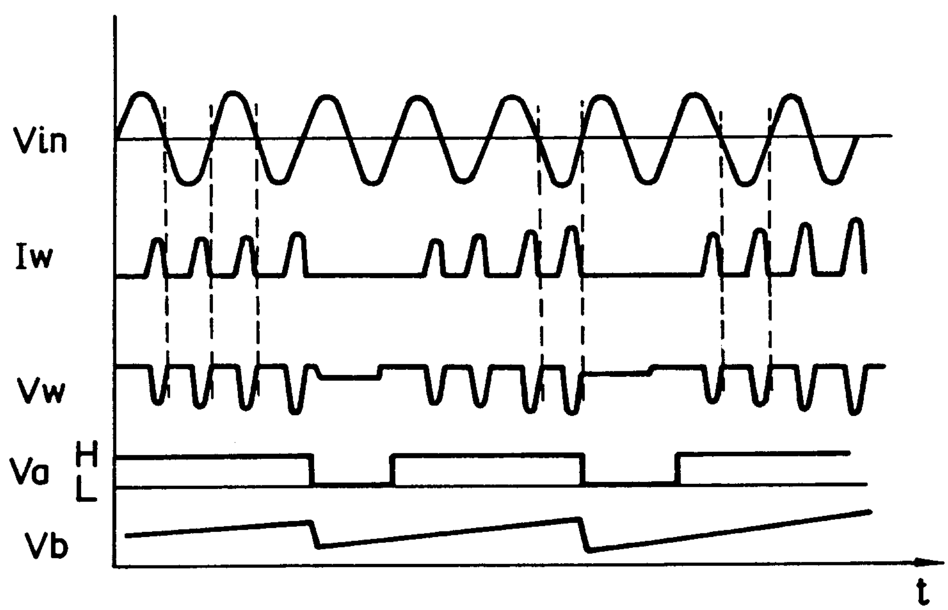

FIG. 7

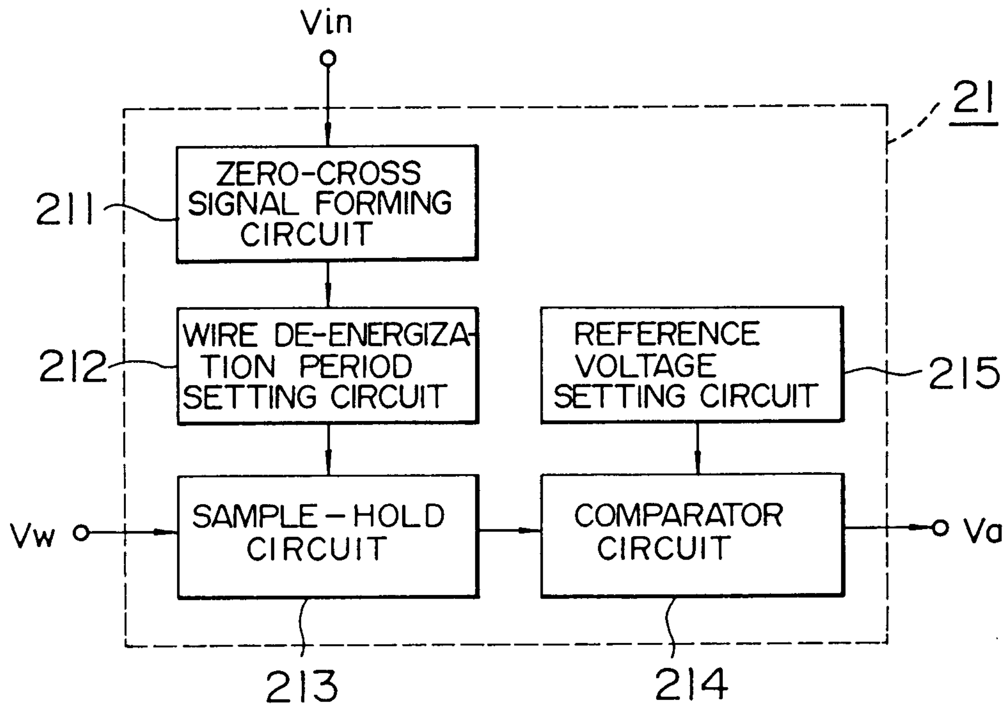
Vin
21
ZERO-CROSS SIGNAL FORMING CIRCUIT
211
WIRE DE-ENERGIZATION PERIOD SETTING CIRCUIT
212
REFERENCE VOLTAGE SETTING CIRCUIT
215
Vw
SAMPLE-HOLD CIRCUIT
COMPARATOR CIRCUIT
Va
213
214

FIG. 8

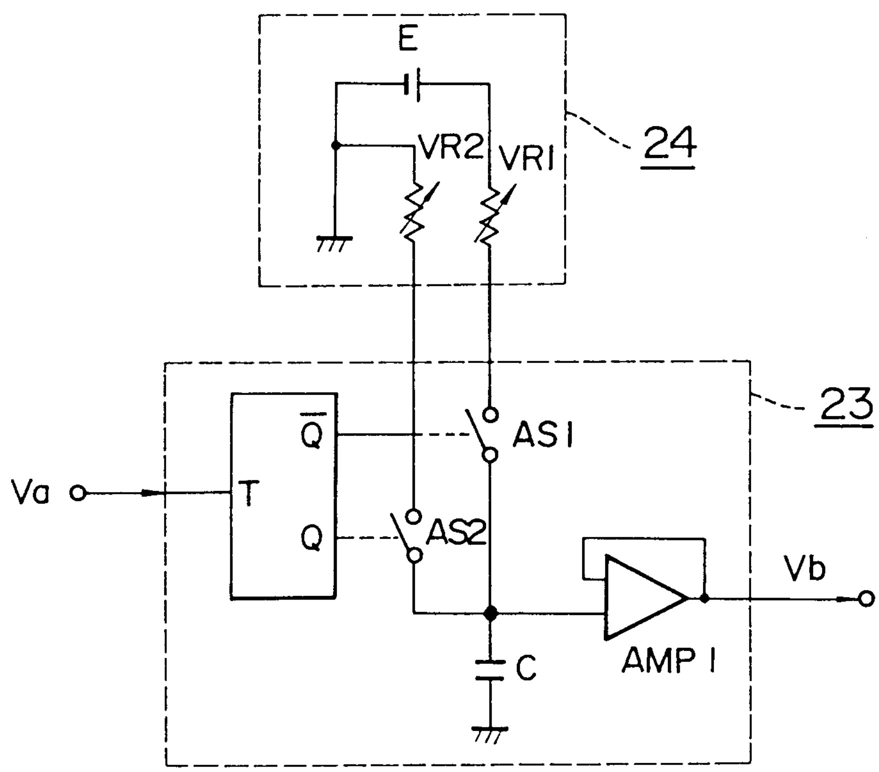
E
VR2
VR1
24
23
Q̄
AS1
Va
T
Q
AS2
Vb
C
AMP 1

FIG. 9

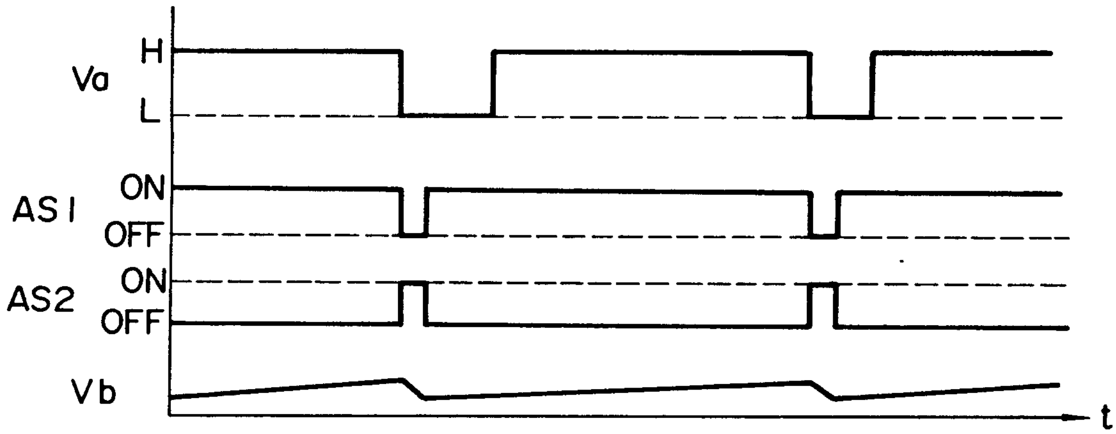

FIG. 10

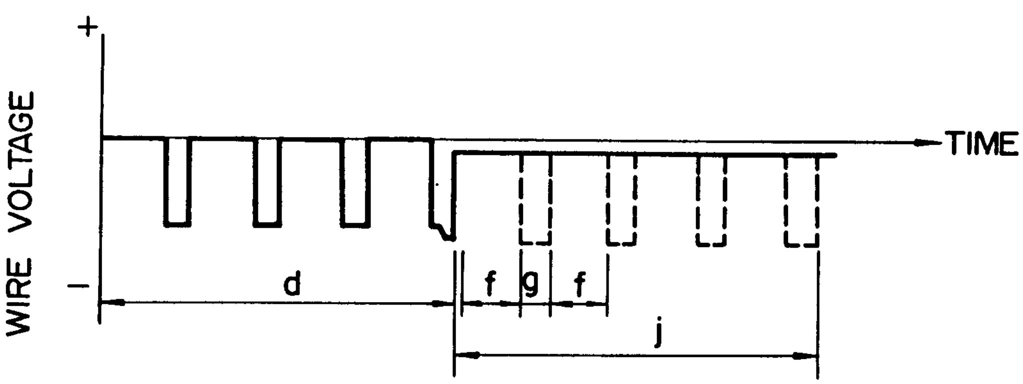

FIG.11

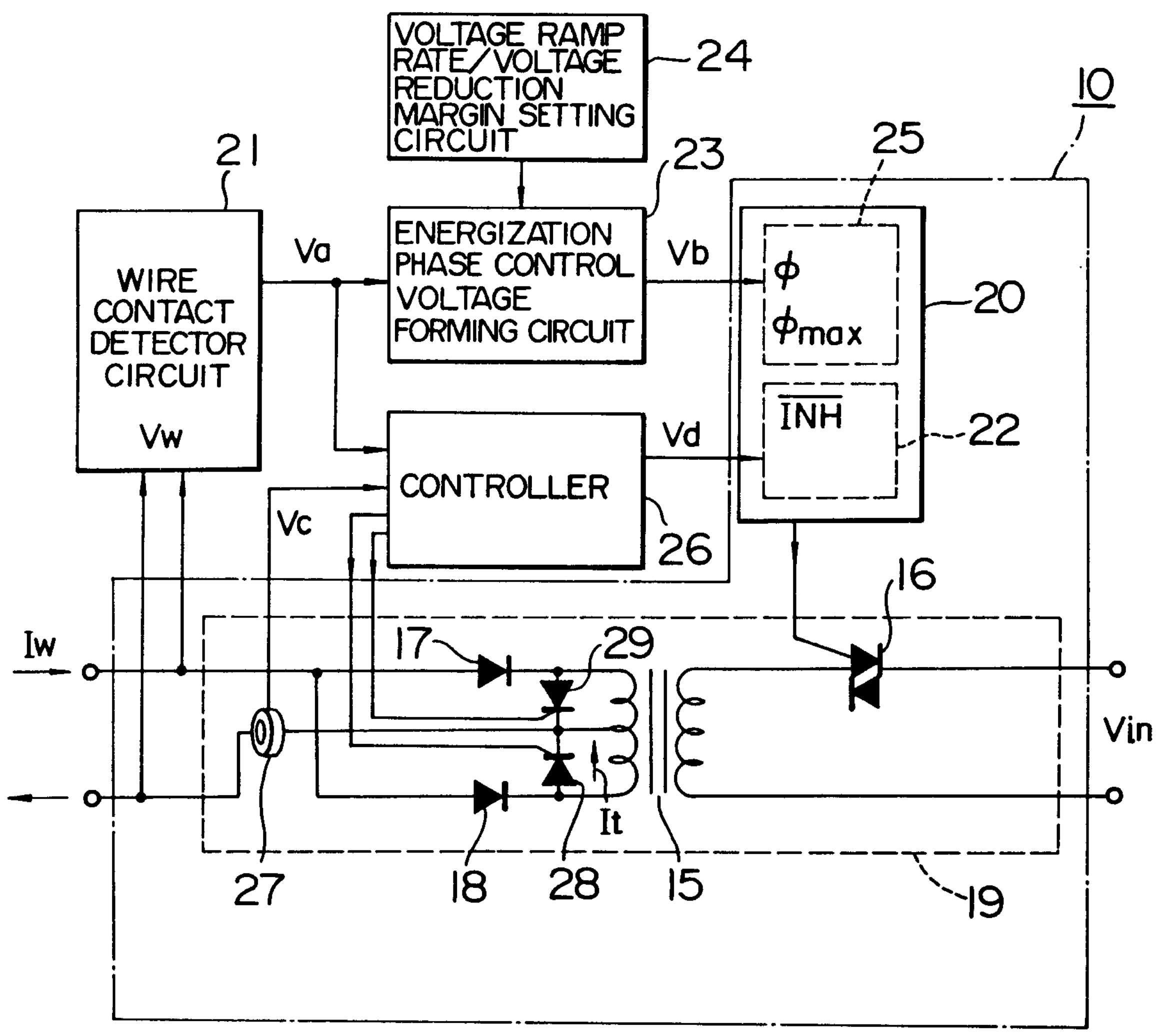
VOLTAGE RAMP RATE/VOLTAGE REDUCTION MARGIN SETTING CIRCUIT
24
10
21
23
25
WIRE CONTACT DETECTOR CIRCUIT
Vw
Va
ENERGIZATION PHASE CONTROL VOLTAGE FORMING CIRCUIT
Vb
φ
φmax
20
INH
22
Vd
CONTROLLER
Vc
26
16
Iw
17
29
Vin
It
27
18
28
15
19

FIG. 12

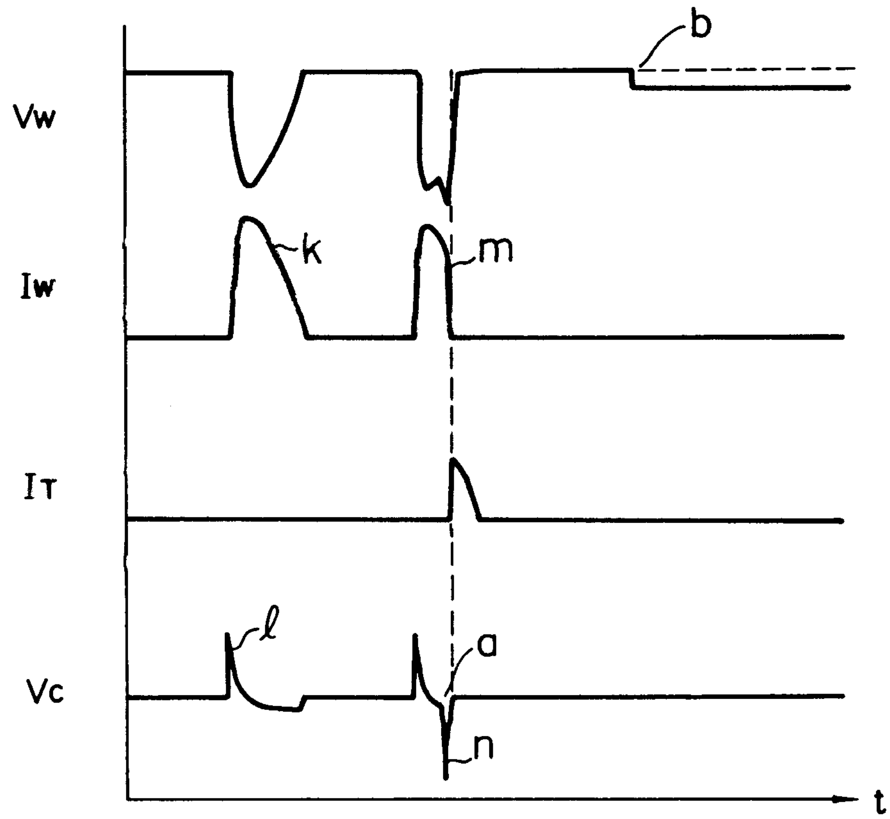
b
Vw
k
Iw
m
IT
ℓ
a
Vc
n
t

FIG. 13

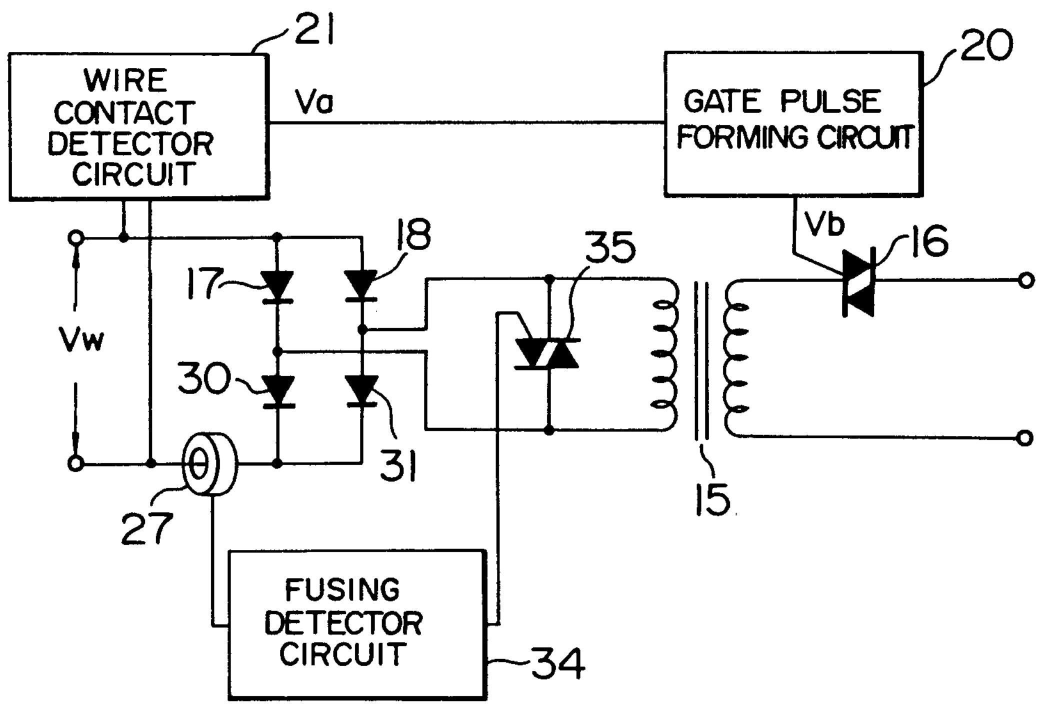
21
WIRE CONTACT DETECTOR CIRCUIT
Va
20
GATE PULSE FORMING CIRCUIT
Vb
16
18
35
17
Vw
30
31
27
15
FUSING DETECTOR CIRCUIT
34

FIG. 14